Title:	Transforming the Uranium Fuel Cycle: Safe & Economical Conversion of DUF6 to DUF4
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Transforming the Uranium Fuel Cycle: Safe & Economical Conversion of DUF_6 to DUF_4

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IMS Rapid Response Roundup
October 9, 2019

SIGMA and Chemistry: The Right Team & Place

SIGMA

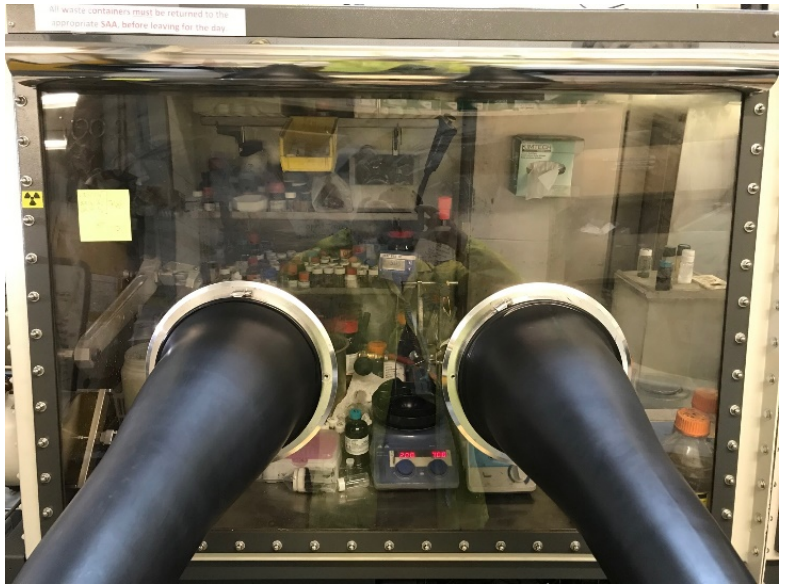
Blake P. Nolen
UF_6 SME, Manages UF_6 Line

UF_6 Line for Handling DUF_6 @ SIGMA

Chemistry

Jaqueline L. Kiplinger
Uranium Fluoride Chemistry SME
Inert Chemistry Facilities

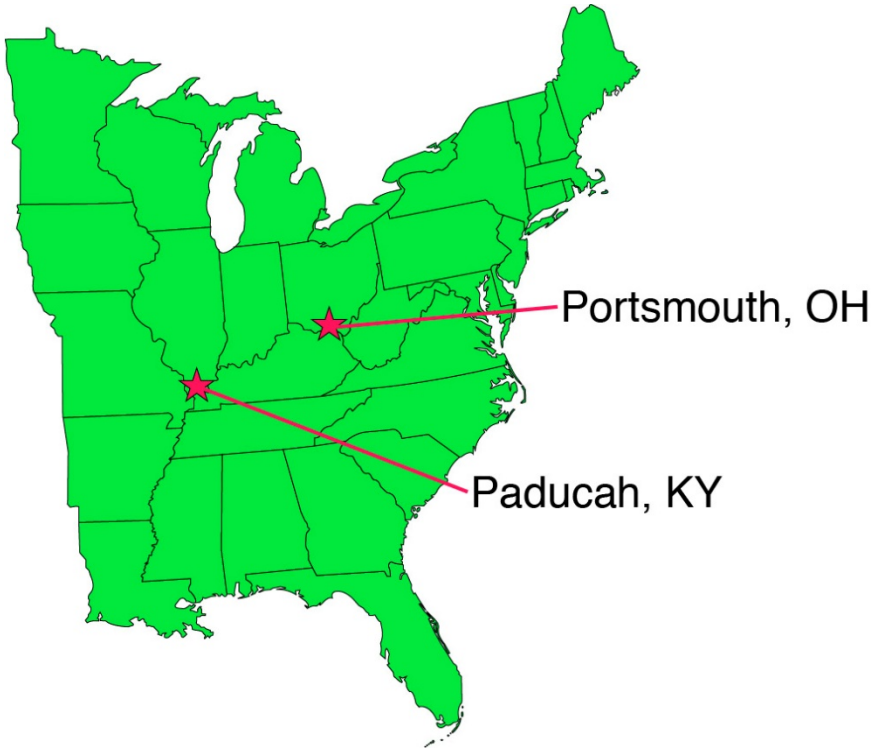
Justin K. Pagano
Chemistry SME
G.T. Seaborg PD Fellow



Inert Glove Boxes for Characterization @ TA-48

A Long-Standing Problem

- 700,000 MT DUF_6 cold war legacy.
- Stored above ground in 70,000 tanks.
- Corrosive and reactive with air, water.



DUF_6 is not stable for long-term storage

Summary of the Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride; Technical Report: LLNL/UCRL-ID-120372; United States, **1995**.

State-of-the-Art for DUF_6 Disposition

$$UF_6 + 2\,H_2O \longrightarrow UO_2F_2 + 4\,HF \quad \textit{TOXIC}$$

$$3\,UO_2F_2 + 2\,H_2O + H_2 \longrightarrow U_3O_8 + 6\,HF$$

FLAMMABLE

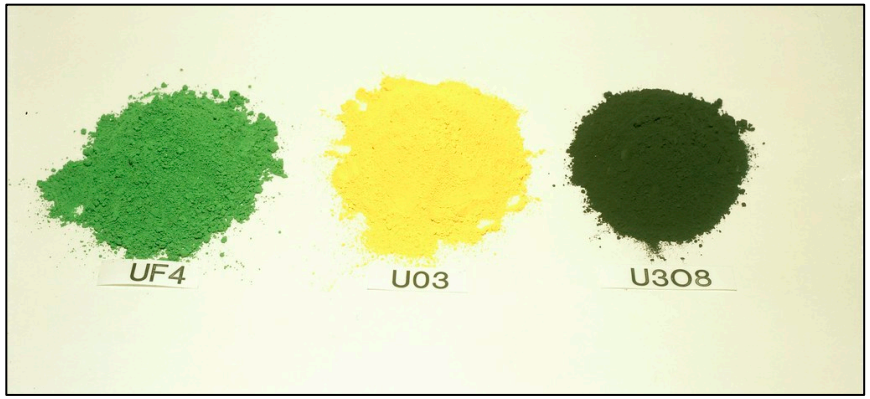
- Autoclave process.
- Requires flammable H_2.
- Produces toxic HF.
- New HF regulatory scares.
- No path forward. Ducrete?

June 21, 2019 - Philadelphia Explosion One in String of 'Near Miss' Accidents at Refineries Using Deadly HF Chemical.

Horowitz, D. This Chemical Kills. Why Aren't Regulators Banning It? *The New York Times*, July 8, 2019.

Why Now: The DUF_6 Disposition Problem is the DU Sustainment Opportunity

- Storage issues only getting worse.
- Extra “line” available at Portsmouth.
- Green chemistry-catalytic process shows great promise.
- UF_4 amenable to above/below ground storage.
- Opportunity for UF_4 “strategic reserve” – ~300 year U.S. uranium supply chain (next slide).



All combined provide a unique opportunity to address two important NNSA problems: Uranium Sustainment & UF_6 Disposition.

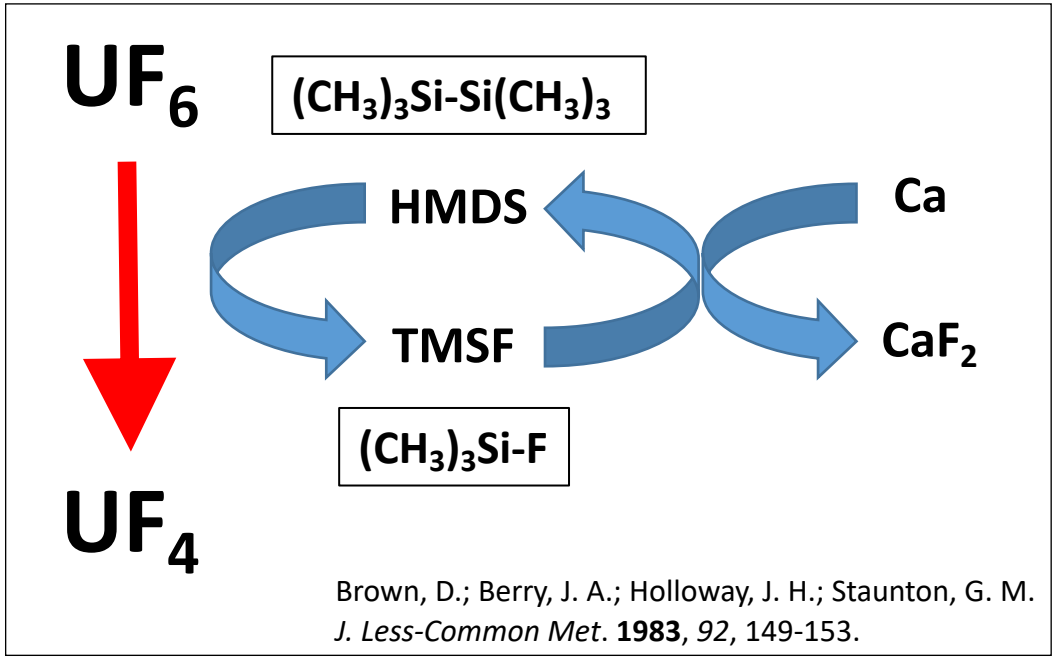
U.S. Uranium Metal Production

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production in Metric Tons	1287	1307	1494	1383	1436	1613	1727	1130	1013	846

- 5 Year Average = 1266 MT/year.
- 700,000 MT of UF_6 @ Paducah and Portsmouth = 238/352 x 700,000, which corresponds to 470,000 MT Uranium Metal … or a ~300 year uranium supply chain at current utilization rate…

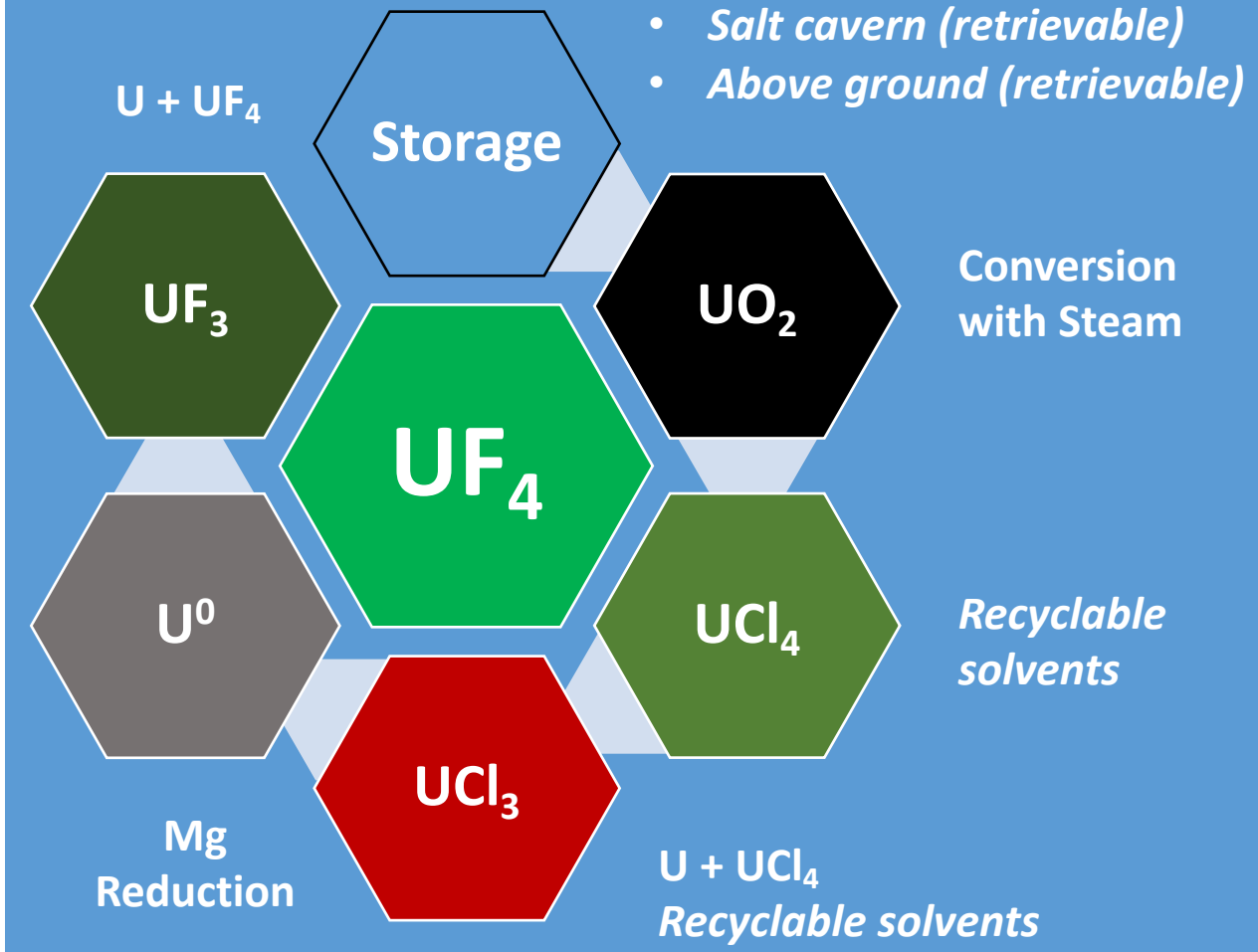
Uranium 2018: Resources, Production and Demand ('Red Book'); NEA-7413; A Joint Report by the Nuclear Energy Agency and the International Atomic Energy Agency; Organization for Economic Cooperation And Development (OECD), **2018**. http://www.oecd-nea.org/ndd/pubs/2018/7413-uranium-2018.pdf

Our Solution



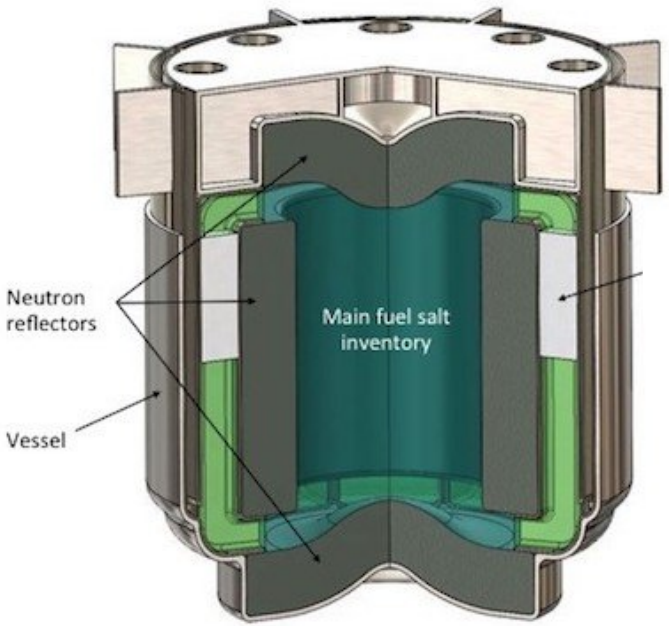
Brown, D.; Berry, J. A.; Holloway, J. H.; Staunton, G. M. *J. Less-Common Met*. **1983**, *92*, 149-153.

- Low temperature process.
- Does not use H_2.
- Does not produce HF.
- Reagents and solvents recyclable.
- Economically, readily scalable.



One Example: UCl_3 and UCl_4 Fuel (90% DU)

MCFR Solutions: Nuclear Innovation for New Options in American Industry



Schematic of MCFR (Molten Chloride Fast Reactor)

- Advance Reactors (MCFR) will need DU for fuel.
- Breeder-Burner Reactors: Burn DU and breed Pu.
- GW class nuclear reactor will need up to ~20 T DU chloride fuel.
- Concerns of fuel cost and scalability.
- There is enough DU to power 400 GW reactors for 400 years.

Proposal Goals

- Validate DUF_6 to DUF_4 chemistry at bench scale.
- Preliminary design for scalable process for DUF_6 to DUF_4 conversion.
- Develop UF_4 routes to other halide materials of interest (e.g. UCl_3, UCl_4).

Will Establish Need for Future Infrastructure Upgrades to Accomplish UF_6 and Chemistry Scale Up at SIGMA, and UF_6 Line at Chemistry for Small Scale UF_6 Manipulations.

Strong Interest from NNSA and Westinghouse to See Our Proposed IMS RR Chemistry Work. ROI Waiting in the Wings …

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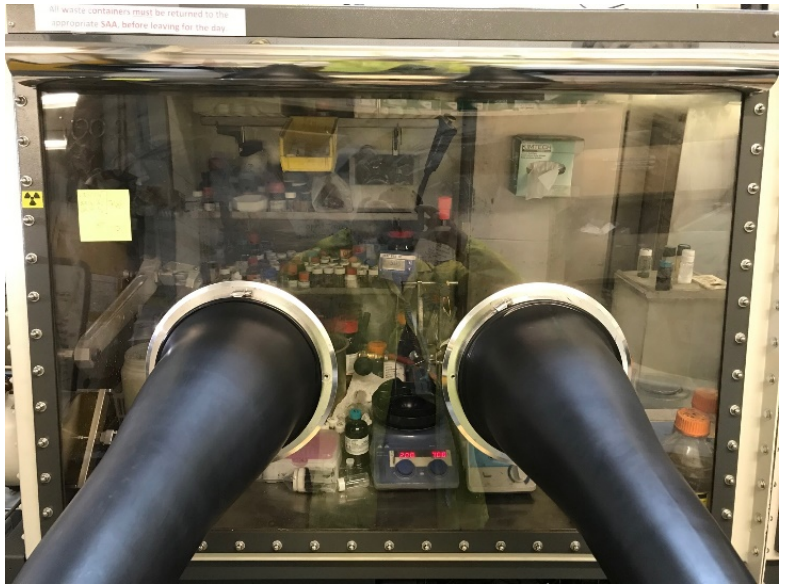
UF_6 Line for Handling DUF_6 @ SIGMA



Inert Glove Boxes for Characterization @ Chemistry

Chemistry

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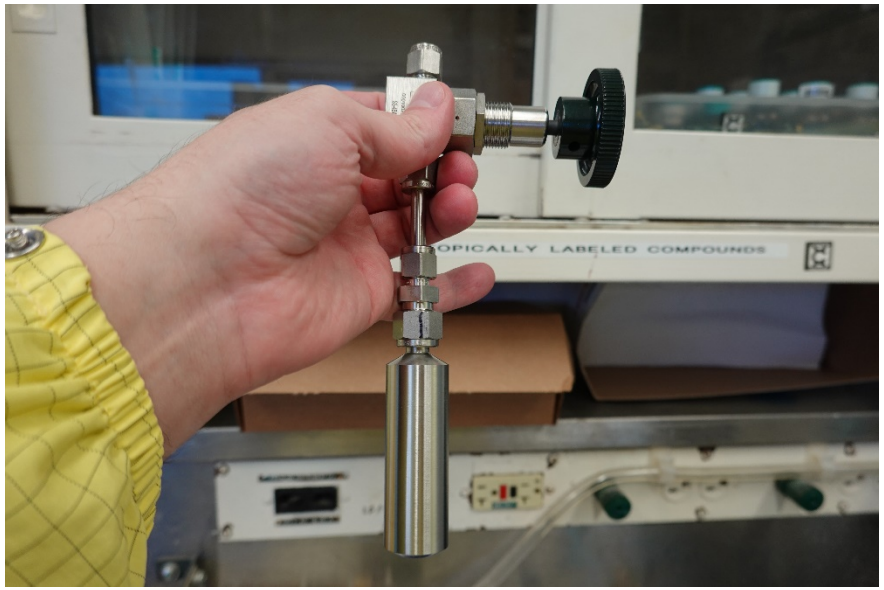
Justin K. Pagano*
Chemistry SME
Post-Doc Ready for Conversion to Technical Staff

**** Recapitalization of Talent***

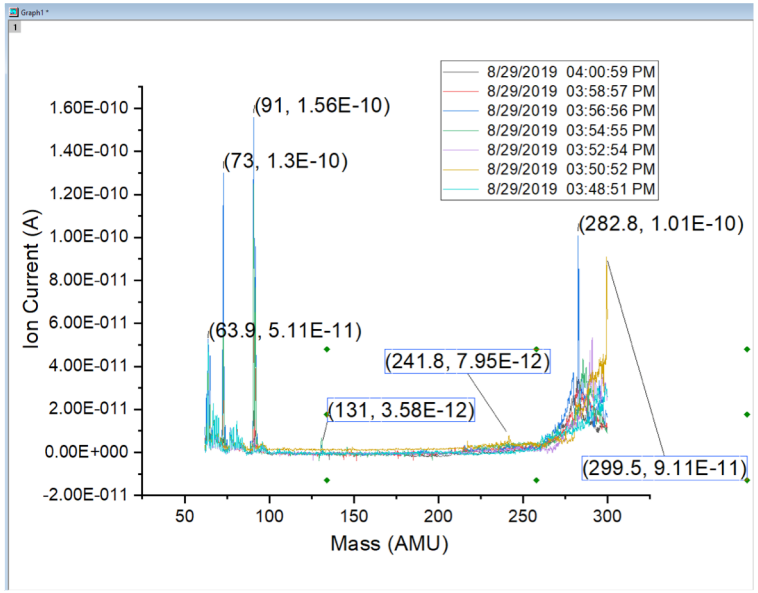
The Process

Chemistry → **SIGMA** → **Chemistry**

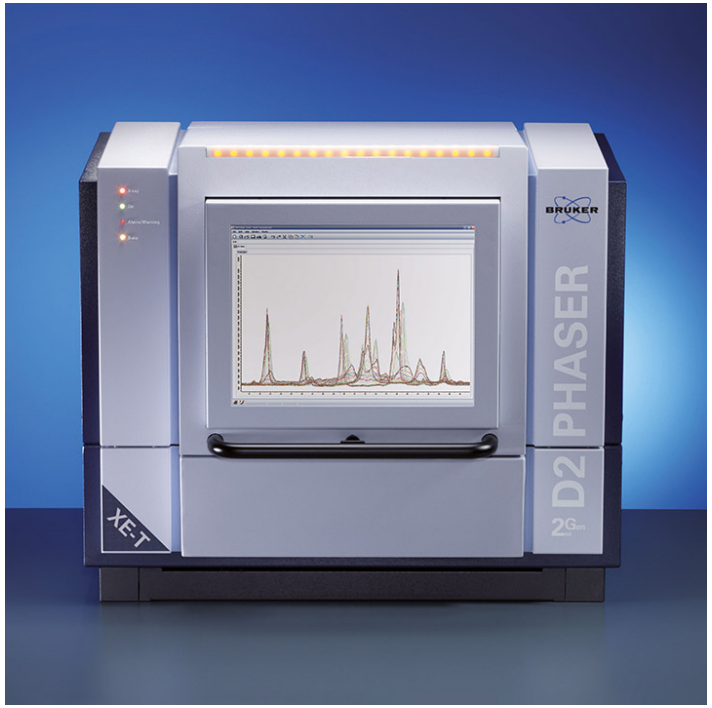
Load sample bottles with solvents/reagents



Add DUF_6, monitor with RGA



Return sample bottle, characterize solid



A simple strategy for success

Project Outcomes

- Designed and fabricated SS reaction vessels for executing reactions with UF_6 at SIGMA, followed by transport and analysis at TA-48.
- Established a new capability at SIGMA for performing small mass transfers of UF_6.
- Safety documentation approved for performing new UF_6 chemistry at SIGMA.
- Staff training and conversion opportunity established for LANL Seaborg post-doc.
- Neat reaction with HMDS $(CH_3)_3Si\text{-}Si(CH_3)_3$ produced fluorosilanes.
- In reactions with solvents, fluorination observed. No DUF_4 observed yet.
- Observations: Only 4 reactions were completed – more clearly needed.
- Due to problems with procurement, we did not get the mass control flow (MFC) unit until late August.
- Due to staff and time shortages UF_4 was never delivered from SIGMA to TA-48 by SHIP-IT.
- Established ability for future collaboration between C and Sigma.